

1. INTRODUCTION

A critical unit operation used with many of the leading water reclamation and air revitalization technologies for advanced life support systems is the fixed packed bed reactor. However, despite many applications for this technology, there is little understanding of how the reduced gravity environment affects the performance and reliability of the reactors. This is especially critical when the reactor involves simultaneous gas and liquid flows. The Packed Bed Reactor Experiment (PBRE) is designed to specifically resolve these technology gaps. The expected outcome of the research effort on the ISS is to develop a set of guidelines and tools to enable engineers to reliably design and operate fixed packed bed reactors for microgravity as well as for the lunar and Martian environments. The PBRE International Space Station (ISS) flight experiment will provide critical hydrodynamic information for this project. The primary objective is to develop and validate macroscopic equations that can be used in partial and microgravity conditions to accurately predict flow pattern transitions, pressure drops, and chemical and biological transport rates in gas-liquid flows through randomly packed beds. The hydrodynamic investigations will focus on the transitions between flow regimes (i.e., bubbly-to-pulse flow transition) and the associated pressure gradients for each flow regime over the range of relevant test parameters (e.g., liquid flow rates, gas flow rates, and particle sizes). These design tools will provide important information for specific water reclamation and air revitalization technologies for advanced life support systems.¹ The photo in Figure 1 shows the experimental equipment with a glass bead test section on a ground test bench in preparation for flight on the ISS.

2. QUALIFY

The feature-rich spectrogram shown in Figure 2 on page 3 was calculated from the Space Acceleration Measurement System (SAMS) sensor es09 measurements made in the US Laboratory module within the Microgravity Science Glovebox (MSG) work volume and near the PBRE test equipment. This plot shows structures, patterns and boundaries in both frequency and time that exhibit strong temporal correlation with independent housekeeping data from PBRE pump operations. The data in Figure 3 show these PBRE housekeeping data for 2 mass flow meters (MFMs) that correspond to MFM34 for the low-flow control loop in the bottom subplot in that figure, and MFM35 in the top subplot for the high-flow control

¹<https://www1.grc.nasa.gov/space/iss-research/msg/pbre>

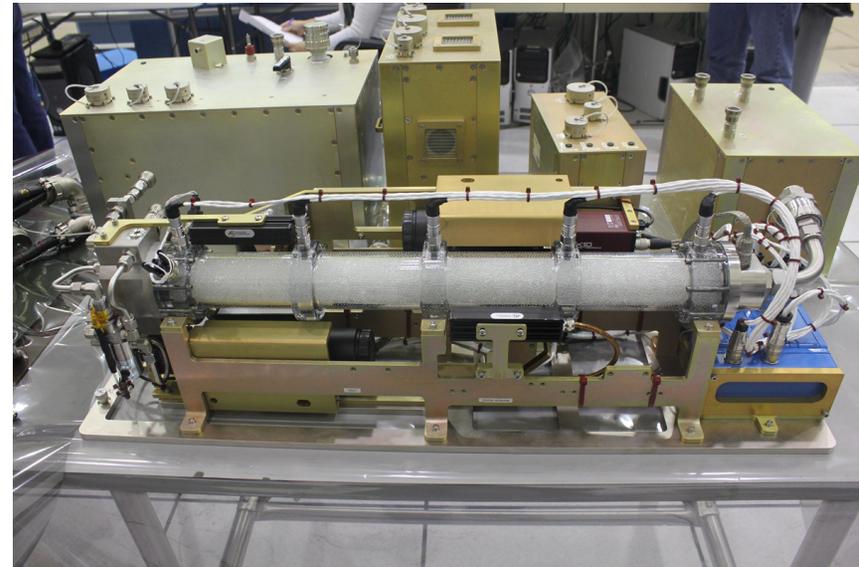


Fig. 1: PBRE Equipment with Glass Bead Test Section.

loop. Careful visual inspection comparing Figure 2 and Figure 3 would likely lead to recognition of the aforementioned temporal correlation, but to see this most clearly, have a look at Figure 4 on page 4. This plot overlays the housekeeping data from PBRE pump operations onto the color spectrogram computed for the SAMS vibratory data. The high-flow data associated with MFM34 is shown as a white trace overlaid toward the bottom of Figure 4, while the low-flow data associated with MFM35 is overlaid as the black trace in that same figure, toward the top. It is clear in Figure 4 that the low-flow loop gives rise to vibrations in the MSG most strongly near 167 Hz (about 10,000 RPM). The high-flow loop imparts its own distinct spectral signature starting most clearly around 57 Hz and with multiple harmonic components all starting and stopping in a temporal pattern that matches the MFM34 readings.

3. QUANTIFY

The interval root-mean-square (RMS) plot of Figure 5 on page 5 shows a portion of the vibratory impact from PBRE pump operations. This plot is focused on the

portion of the acceleration spectrum between 80 and 100 Hz and from this we see a baseline RMS level of about 100 μg with pumps off and then in excess of about 400 μg and at times approaching nearly 500 μg when the pumps are operating.

The spectrogram plot of Figure 6 on page 6 shows a black trace overlay, which is the interval RMS data from the plot of Figure 5. This correlates well in time with the high-flow PBRE pump signature, of course, since we were focusing on a frequency band that was associated with that feature obvious in the vibratory acceleration spectrogram.

4. CONCLUSION

The pump operations associated with PBRE produce a strong spectral signature with vibrations that appear localized within the MSG work volume. The PBRE pump operations signature is quite distinctive...actually, it's 2 signatures: one for the low-flow loop and the other associated with the high-flow loop. These spectral signatures are readily trackable via SAMS vibratory sensor data when watching a real-time spectrogram for the sensor inside the work volume. The full impact of these vibrations is difficult to parse out for quantification since it is spread across nearly the entire acceleration spectrum and other, strong disturbances are present throughout. A well-designed series of notch filters could be employed to further isolate and thereby better quantify the impact. If such an analysis would help your work, then please send an email request to pimsops@grc.nasa.gov.

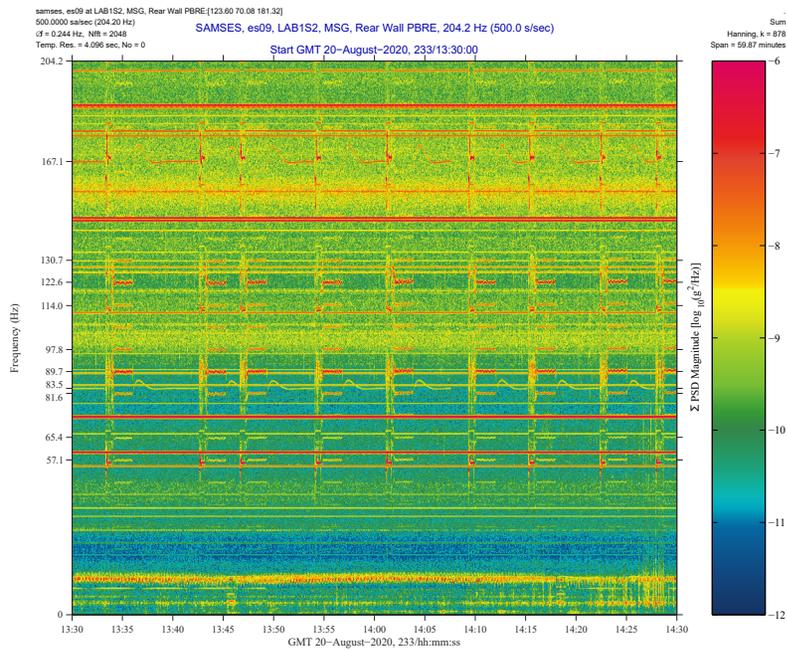


Fig. 2: Spectrogram showing PBRE pump operations on GMT 2020-08-20.

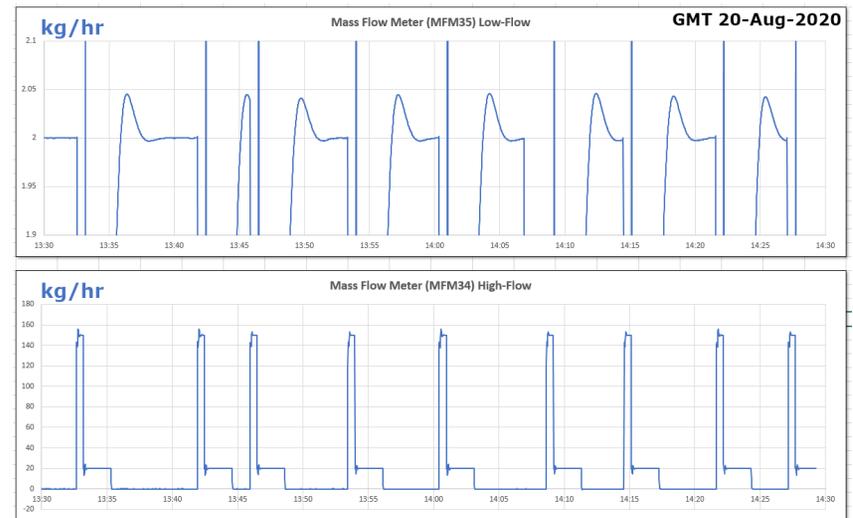


Fig. 3: PBRE Mass Flow Meter Housekeeping Data (MFM34 & MFM35).

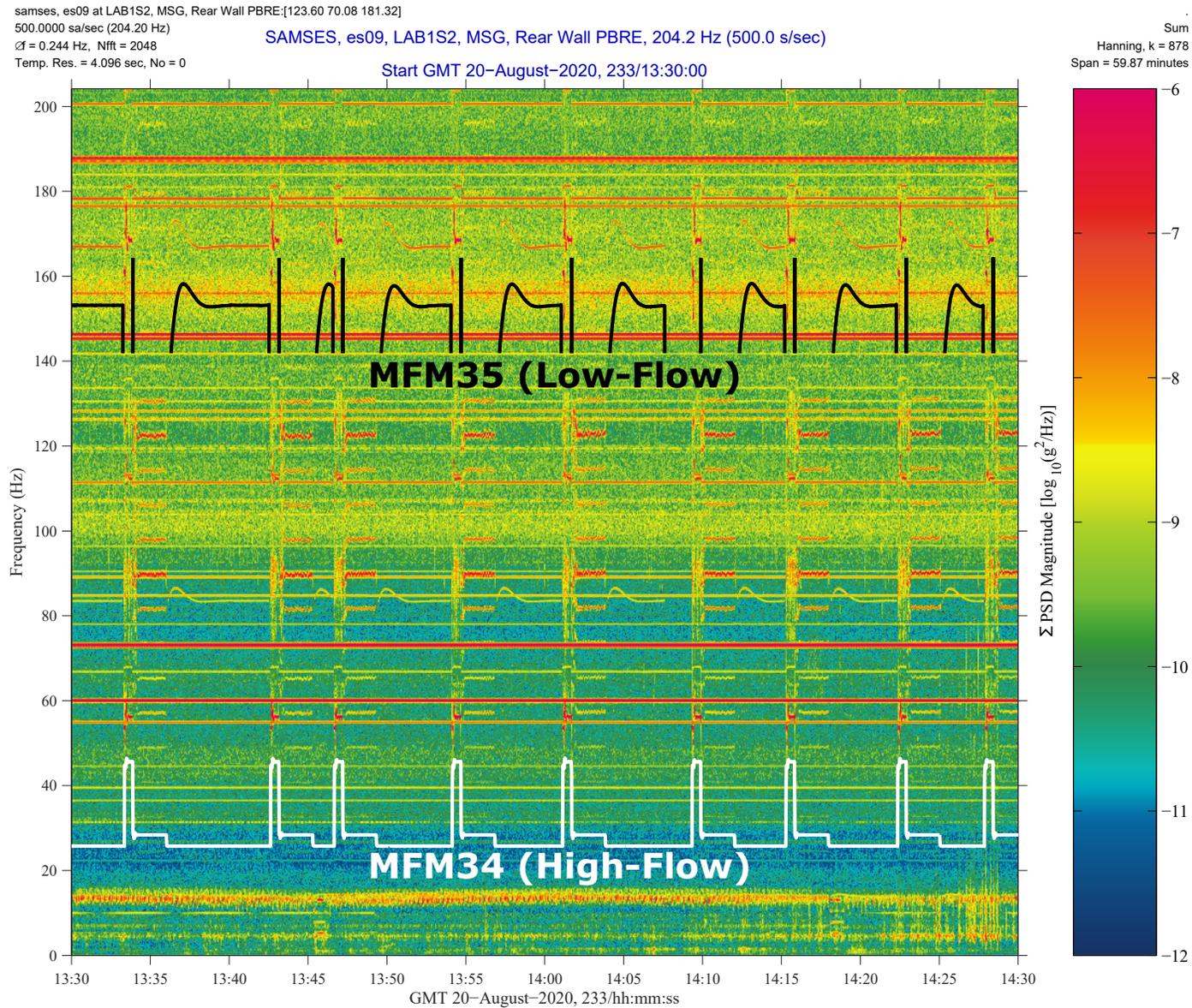


Fig. 4: Spectrogram showing PBRE pump operations on GMT 2020-08-20 with overlays of mass flow meter readings.

samses, es09 at LAB1S2, MSG, Rear Wall PBRE:[123.60 70.08 181.32]
500.0000 sa/sec (204.20 Hz)
 Δf : 0.122 Hz, Range: 80 - 100 Hz
Temp. Resolution: 4.096 sec

SAMSES, es09, LAB1S2, MSG, Rear Wall PBRE, 204.2 Hz (500.0 s/sec)

SSAnalysis[0.0 0.0 0.0]
Hanning, k = 1

Start GMT 20-August-2020, 233/13:30:00

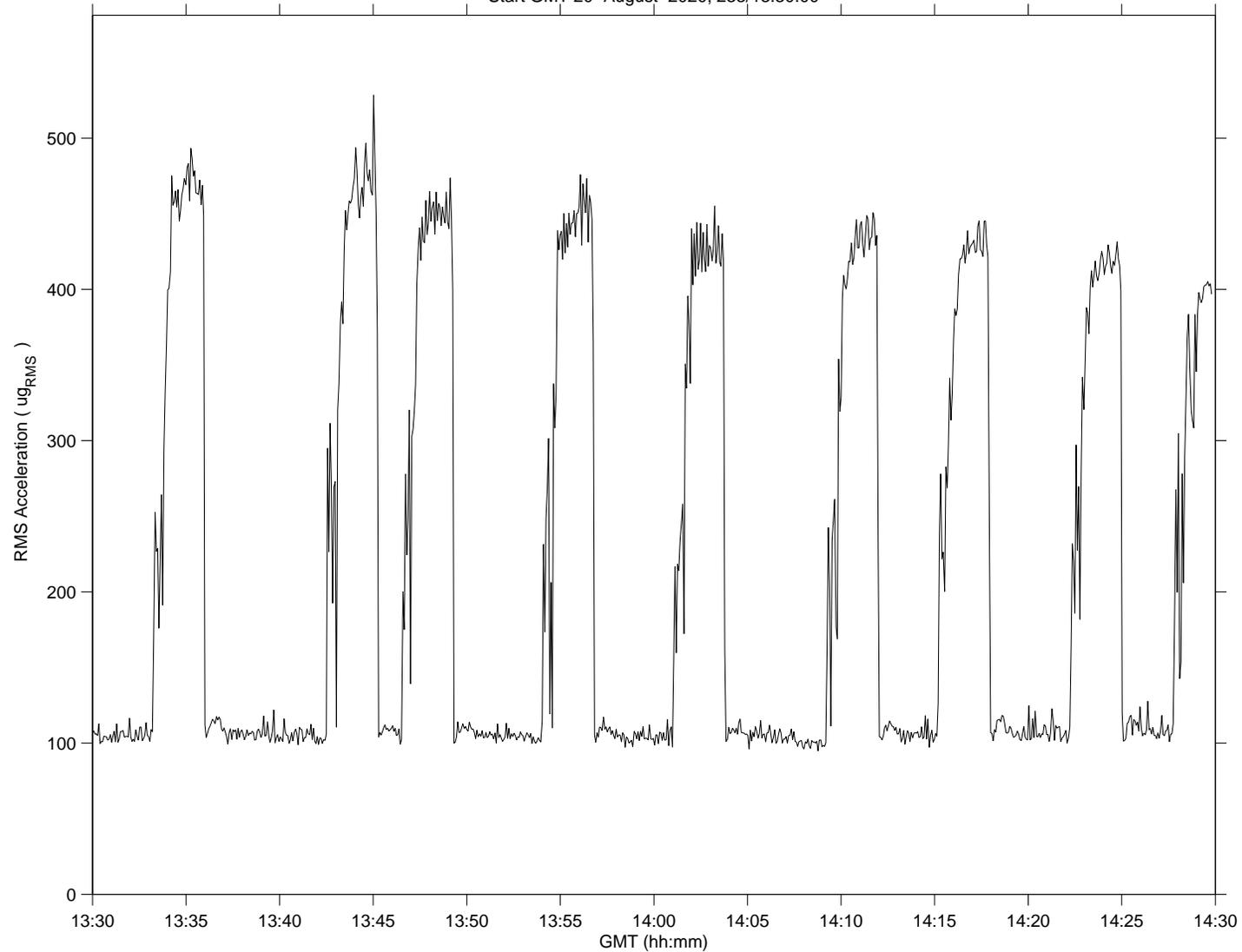
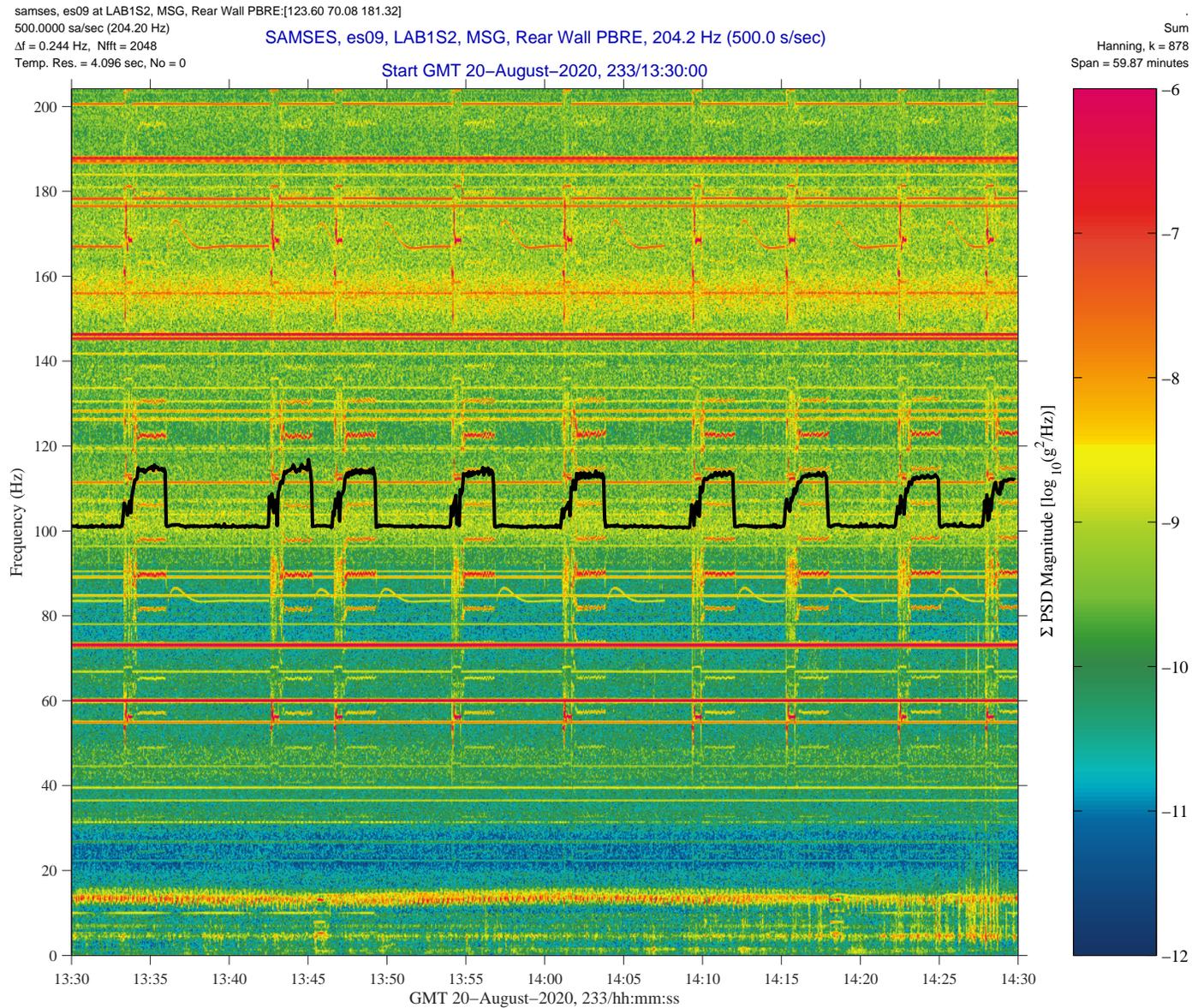


Fig. 5: Interval RMS for 80 Hz < f < 100 Hz.

Fig. 6: Overlay color spectrogram with interval RMS for $80 \text{ Hz} < f < 100 \text{ Hz}$.